IMPROVEMENT OF CLUSTER HEAD SELECTION IN LEACH PROTOCOL OF WIRELESS SENSOR NETWORK

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ABSTRACT

WSNs suffer from many issues such as coverage, security, energy-efficiency and localization. Among these issues, energy-efficiency is the most critical, as sensor nodes are battery operated, hence the need to optimize energy. Clustering technique has shown to be more suitable for energy efficiency, which is why LEACH protocol is considered. Despite that, the LEACH algorithm shows some drawbacks in the area of energy efficiency that needs to be enhanced in order to improve its performance. Therefore, since routing, communication and broadcasting between the nodes are done by the cluster heads, a modification in the LEACH algorithm was proposed where the improvement was done in cluster head selection to reduce the energy consumption. In this thesis, unlike the LEACH which uses the residual energy of the entire network, the cluster head selection takes into account the residual energy of each node to calculate the threshold value for next round. The cluster head selection uses a modified stochastic algorithm- the deterministic algorithm which calculates the residual energy of each node after each round to select the node with the highest residual energy as the cluster head. This approach makes the clustering algorithm adaptive to network dynamics as each node is considered to be a cluster head at a point. For simulation, the approach is implemented with LEACH in OMNET++ with Castalia and the results show that there is 3% increase in network lifetime.

ABSTRAK

WSN mengalami banyak masalah seperti liputan, keselamatan, kecekapan tenaga dan penyetempatan. Antara isu-isu ini, kecekapan tenaga adalah yang paling penting, kerana nod sensor adalah bateri yang dikendalikan, oleh itu keperluan untuk mengoptimumkan tenaga. Teknik kluster telah menunjukkan lebih sesuai untuk kecekapan tenaga, oleh itu mengapa protokol LEACH dipertimbangkan. Walau bagaimanapun, algoritma LEACH menunjukkan beberapa kelemahan dalam bidang kecekapan tenaga yang perlu dipertingkatkan untuk meningkatkan prestasinya. Oleh itu, memandangkan penghalaan, komunikasi dan penyiaran di antara nod dilakukan oleh ketua kluster, pengubahsuaian dalam algoritma LEACH telah dicadangkan di mana penambahbaikan dilakukan dalam pemilihan kepala kluster untuk mengurangkan penggunaan tenaga. Dalam tesis ini, tidak seperti LEACH yang menggunakan tenaga sisa keseluruhan rangkaian, pemilihan kepala kluster mengambil kira tenaga sisa setiap nod untuk menghitung nilai ambang untuk pusingan seterusnya. Pemilihan kepala kluster menggunakan algoritma stokastik diubahsuai - algoritma deterministik yang mengira tenaga sisa setiap node selepas setiap pusingan untuk memilih nod dengan tenaga sisa tertinggi sebagai kepala kluster. Pendekatan ini menjadikan algoritma kluster menyesuaikan diri dengan dinamik rangkaian kerana setiap nod dianggap sebagai kepala kluster pada satu titik. Untuk simulasi, pendekatan ini dilaksanakan dengan LEACH di OMNET ++ dengan Castalia dan hasilnya menunjukkan bahawa terdapat kenaikan 3% dalam jangka hayat rangkaian.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In pervasive computing, a new technology of network has been the center of research. The class of network is referred to as Wireless Sensor Network (Akyildiz *et al.*, 2002; Anastasi *et al.*, 2009). This technology is aimed at providing efficient, effective and qualitative inter-connection between the human world and the computer world. Applications of sensor networks include but are not limited to: monitoring of environmental changes, prediction and relief of natural disaster, security area, and healthcare sector, manufacturing industries, transportation and day-to-day home appliances. When applied to health type applications, they are referred to as Health Care Wireless Sensor Networks (HCWSNs) (Malan *et al.*, 2004), that is related to Wireless Body Network. The difference between WLAN and WSN technology application is the criticality and excellence reliability of data transmission which has a number of characteristics that differentiate them from application. Hence reliability is of paramount importance in WSNs.

A WSN is defined as a network that consists of sensors (several sensor nodes) with capabilities of sensing wireless communications and computing. These sensor nodes are disseminated in an unattended atmosphere (the sensing area) to sense the physical realm. The data that has been sensed can be gathered by a few sink sensor nodes that can access network infrastructure; e.g. internet. In the end, the user can remotely retrieve the data sensed by accessing the infrastructure networks. These networks are capable of collecting audio, seismic wave and other types of data. They collaborate to carry out a high level duty in the network. The wireless environment consumes substantial amount of energy, so there is need to reduce the amount of energy expended by the sensor nodes for transmission and reception of data. Presently, researchers direct their strength in sensor networks with focus on matters that involves development of energy efficient protocol, cost effective, safe and fault tolerance networks.

Figure 1.1 shows a general architecture for WSN. It is important to note that this illustration is not peculiar to any particular system; it only shows the relationship of classes of components or devices with one another. In general sense, the operation of WSN involves acquisition of data and reporting of data. So, there is a network for acquisition of data and network for distribution of data and a center that takes care of monitoring and control (Lewis, 2004) as illustrated in Figure 1.1. The Figure shows two kinds of network topologies. The sensor nodes either form a first node dead in which the nodes perform function of routers that transfers data across a multi-hop routing to a sink or a half node dead in which more powerful fixed or mobile relays are used to bring together and connect the sensor data to a sink.

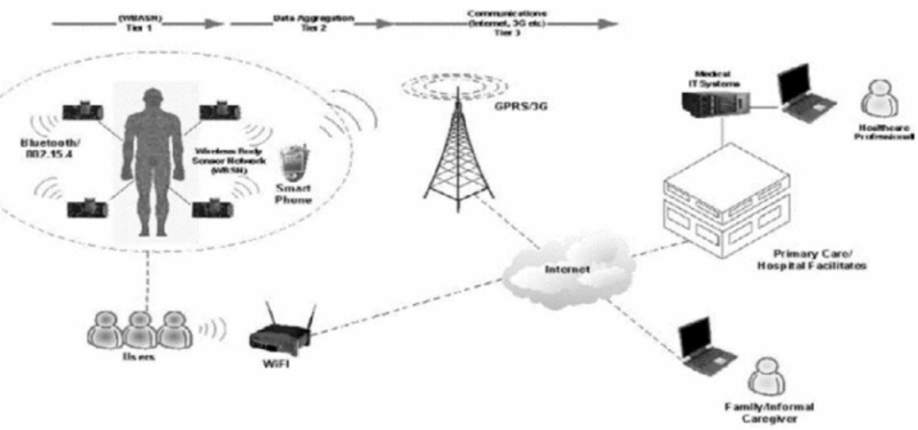

Figure 1.1: The Wireless sensor node architecture (Lewis, 2004)

Figure 1.2 illustrates the structure of a basic sensor node. A sensor node basically comprised of five major components that are- memory, sensor nodes, CPU, transceiver and power supply (Anastasi et al., 2009; He et al., 2006) - memory as usual store data and programs; sensor nodes observe physical parameters of the area; CPU handles all applicable data and have the capability of executing code, transceiver sends and receives information over a wireless medium and batteries are often used to serve as power supply. The Figure 1.2 shows the architecture of sensor node.

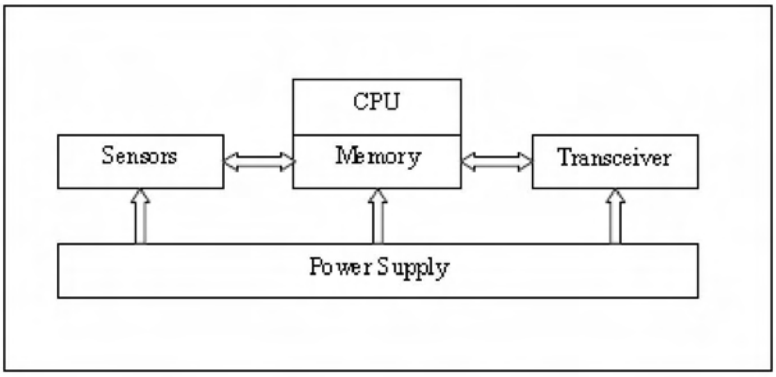

Figure 1.2: Sensor Node Architecture (He et al., 2006)

Data is collected from the WSN at the base station. The data from the environment are collected by the sensor nodes, local processing is performed and then the data is send to the base station. The data is integrated and transmitted to the users at the base station by the internetworking medium like the internet, satellite or WAN/LAN (Akyildiz *et al.*, 2002; Frikha and Slimane, 2006). In comparison with the sensor node, the base station has stronger communicating and processing abilities because of its unlimited energy supply. Data sensing and reporting depends on the application in WSNs. It is classified based on time driven or event driven (Virone *et al.*, 2006; He *et al.*, 2006;Wang and Xiao, 2006). In time driven networks, sensor node switch on their sensors from time to time, sensing surroundings and send the sensed data at periodic interval; while in event driven networks, sensor nodes react instantaneously to abrupt changes due to the occurrence of an event. In most cases of event driven applications, for example when sensor nodes detect fire, data must be send and arrive at the BS as rapidly as possible. WSNs can be of single hop or multi hop communications, Anastasi *et al.* (2009); Virone *et al.* (2006); Tilak *et al.* (2002). In a single-hop communication, a sensor node communicates with other sensor nodes or with a base station; but in multi-hop, sensor node may comprise series of hops to communicate with one another or with a base station. The fact that wireless sensor nodes has limited power resources- the batteries, optimization of power efficiency is essential to maximize the life span and reliability of the wireless sensor networks.

1.2 Problem Background

In general, the Wireless Sensor Networks consists of a large number of small and cheap sensor nodes that have very limited energy, processing power and storage. They usually monitor areas, collect data and report to the base station (BS). Due to the achievement in low-power digital circuit and wireless communication, many applications of the WSN are developed and already been used in habitat monitoring, military formation and object tracking. The energy consumption can be reduced by allowing only a portion of the nodes, which called cluster heads, to communicate with the base station. The data sent by each node is then collected by cluster heads and compressed. After that the aggregated data is transmitted to the base station. Although clustering can reduce energy consumption, it has some problems. The main problem is that energy consumption is concentrated on the cluster heads. In order to overcome this demerit, the issue of how to distribute the energy consumption in cluster routing must be solved. The representative solution is improved cluster head selection in LEACH, which is a deterministic clustering method.

WSNs have many limitations which must be considered in design of protocol for these sensor networks. A key factor in sensor networks worthy of consideration is the amount of energy required for sensing, computation and communicating (He *et* *al.*, 2006; Yick *et al.*, 2008; Liang *et al.*, 2008). Given that replacing batteries may be demanding or somehow impossible in many applications and since the life span of a sensor node rely solely to a large degree on the life span of the batteries as well as the network coverage and connectivity, it is crucial to tailor energy efficient approaches for these networks. Sensor nodes are set out at random in the sensing field, with the expectation that they perform without any factor that limits the energy availability to the sensor nodes. Some existing routing protocols meant for conventional networks cannot work properly in most network setup due to:

i. The data collected by the multiple sensor nodes is centered on a common event and there is a degree of redundancy in the sensed data.
ii. Sensor networks are specific for a particular application.
iii. Sensor nodes are immobile, that is they are not mobile.
iv. Sensor networks have substantial numbers of sensor nodes which does not need distinct addresses because maintaining so many addresses means having additional overhead.
v. Since sensor networks are unattended and all network organization and configuration operates automatically, there is need for sensor nodes to be self-organized.
vi. Data collection in the sensor network is centered on location.

Therefore for such situations, there is need to have a method that will provide a dependable and fault tolerant communication, fast reconfiguration and least consumption of energy. Routing protocols play a vital role in most, if not all of these activities. Besides the infrastructure less, inadequate resources in relation to energy, space and computational capabilities nature of WSNs makes routing more difficult. A lot of routing protocols have been deployed to address all the aforementioned problems but some of which are more appropriate in some scenarios having better performance while not suitable in other situations having significant limitations taking into consideration the architecture and application demands of WSNs. So, it is vital to evaluate routing protocols for applications.

In this research work, an effective cluster head selection technique which can overcome the deficiencies of the LEACH algorithm is proposed. LEACH being the protocol widely used for energy efficient routers needs improvement on the energy, that is why the enhancement done on it. The selection of cluster heads is primarily based on the residual/current energy of the nodes. Data transmission overhead can be reduced by considering the distance factor between the CH and sink. Thus, those nodes having high residual energy and at the same time having low distance with respect to sink are elected as cluster heads. Also, during the cluster formation phase, a distance-based approach is undertaken for the selection of a CH by a non-cluster head node.

LEACH cluster-heads are randomly selected using probability variables. In order to select cluster-heads, each node ***n*** determines a random number between 0 and 1**.** If the number is less than a threshold *T(n),* the node becomes a cluster-head. This method is enhanced by using a modified stochastic threshold algorithm, which is the deterministic algorithm. This overcomes the problem of the random selection based on probability.

1.3 Related Work

Many new algorithms and protocols that deal with energy efficiency have been developed over recent years, Uthra et al. (2012). Low Energy Adaptive Clustering Hierarchy (LEACH) is an intelligent hierarchical protocol that is clustering-based, Heinzelman et al (2000). It can effectively optimize the energy consumption in sensor network. From LEACH, many protocols have been given birth. The protocol procedures are closely and firmly united and also go well with homogenous and heterogeneous sensor environments. LEACH focuses mainly on the idea of cluster head selection by the cluster members to avoid enormous energy consumption. Despite this, LEACH still can have certain demerits such as:

i. In the cluster head election phase of the LEACH protocol, there is a probability that some nodes with minimum energy will get selected as the cluster head in all iterations. This results in uncontrolled use of limited battery power by the node.
ii. Overhead due to data transmission.
iii. During the cluster formation stage, some non-cluster head nodes may join a cluster, such that the distance between its cluster head and the base station will be even greater than the distance between that particular sensor node and the base station.

The concept of cluster centered routing is exploited for the heterogeneous sensor network in the LEACH scheme to enhance the network lifetime, Heinzelman et al. (2000). In this work, each and every weighted election probability for each node is calculated to decide the success of a node to be cluster head or not. For a hierarchical WSN, the cluster head selection process is in a distributed way, Dilip et al. (2009).

Tang et al. (2010) handled the clustering problem of WSN by the chain head selection method. This work is able to achieve better energy saving than the conventional LEACH protocol. LEACH-VF virtual forces protocol is another work used to solve the selection problem by overlapping sensing holes upon the sensing coverage, Yassein et al. (2009). But the energy efficiency is slightly compromised, while solving the area problem. In the protocol, time-based applications are focused by controlling data transmission over the CH, Manjeshwar & Agrawal (2000).

LEACH-C; (Geetha et al., 2012) an extension of LEACH algorithm is based on centralized clustering. In LEACH-C, using a centralized clustering protocol, the steady state stage is quite similar to LEACH. In the set-up phase, each and every sensor node sends the current position and the battery level to the BS. Using the global network data the BS selects better clusters that require the minimal power for data transmission. A Global Positioning System (GPS) or the some other location tracking technique is necessary to find the current location. Cost is the considerable factor here. The BS then broadcasts the information to all sensor nodes in the network. Optical-LEACH (O-LEACH) is introduced as an optical, low-energy, adaptive clustering hierarchy, which is again an improved form of LEACH protocol; El Khediri et al. (2014). In the research, the node whose current energy is greater than ten percent gets the chance to act as a CH.

Another enhancement of the LEACH algorithm is carried out as a Two-Level Hierarchy LEACH- “TL-LEACH”. TL-LEACH has a bi-stage CH selection, which includes primary and secondary stage and this process serves as a single stage in LEACH. The CH elected by the primary stage connects with the secondary CHs, and the consequent secondary CHs get connected with their cluster members. Similar to LEACH, data fusion will also happen here (Loscri et al., 2005). Data transfer from the source node to the BS could be attained in two steps: Initially the secondary CHs accumulate data from their respective cluster members and thus collected data are fused for further processing. Thus fused data are collected by the primary CHs and the second level data fusion is done in the primary cluster head. This in turn reduces the battery consumption, ultimately reducing the total energy usage.

1.4 Problem Statement

While literature reviews, it has been analyzed that most LEACH protocols are energy unbalanced due to the issue of random cluster head selection and uneven cluster head distribution. As energy is a very crucial resource in WSNs, the future work will be concentrated on how to make the LEACH protocol more energy efficient and balance energy consumption within the network through improved cluster head selection. The concentrated parameter of this proposed work is the residual energy of the nodes and the distance between cluster heads. The proposed work will focus on an improved process of selecting the cluster head. The LEACH protocol will be analyzed and area of improvement will be focused to make it energy efficient. For analysis, a simulator will be used.

It has been observed that many researches that have been done on the area of energy consumption in WSNs show that about 70% of the energy is being consumed during the data transmission phase. Therefore, energy consumption is among the main problems in WSNs application. In WSN applications, the sensor nodes are usually deployed in an unattended field or environment and replacement of batteries is very difficult if not impossible. These sensor nodes are used to transmit accurate sense information of some resources to the base station for analysis. These communication activities cause the depletion of the SN's energy quickly which reduces the network lifetime; therefore exposing the patient life into risk due to the need of real time information about the patient condition and the current location of the doctors/nurses in case of any emergency. So there is a need to improve the cluster head selection process to achieve higher efficiency and life span.

1.5 Research Questions

To overcome the problem statement of this study, the main research question is:

"How to reduce energy consumption in wireless sensor networks for wireless sensor network applications by improving the cluster head selection process?"

1.6 Research Objective

The aim of this research is design of an enhancement of cluster head selection based on LEACH routing protocol that is used in WSN applications to improve energy efficiency and network lifetime.

To achieve this aim, the following objectives were identified:

i. To design a cluster head selection technique based on LEACH.
ii. To implement the cluster head selection technique by using the deterministic threshold algorithm stochastically.

1.7 Scope of Work

This study is limited to cluster-based routing protocols, with particular emphasis on energy efficiency. A cluster-based energy efficient routing protocol, the Low-Energy Adaptive Clustering Hierarchy (LEACH) is considered because this protocol consumes low amount of energy as compared to others. The analysis will be carried on the LEACH protocol and the improved cluster head selection to determine their performance, energy efficiency and lifetime. OMNeT++ will be used as the simulation tool. The research does not take into account of other routing protocols. The domain of the study is the LEACH protocol.

1.8 Significance of Study

In this research, an energy-efficient communication protocol for WSNs, that is LEACH cluster-based routing protocol is studied with the aim of enhancing the cluster head selection process to improve performance, energy reduction and network lifetime. Data from member nodes are collected by the cluster heads, aggregation of the data is done and the aggregated data is transmitted to the base station for higher level processing. In order to prolong the network's life span for data communication, it is vital to focus on how to reduce energy consumption in the WSNs. The protocols divide the sensor network into clusters of nodes headed by a cluster head; these clusters are used to form a logical hierarchy in a flat topology. The proposed improvement in the cluster head selection is therefore dynamic because it adapts to changes in network connectivity and reduces energy consumption. Energy conscious protocol LEACH would be adopted based on various network topologies.

The result of the analysis will show how large amount of energy is saved by using the improved cluster head selection, ultimately reducing energy consumption and communication overheads within the sensor networks. This will justify the advantages of using the improved clustering process.

1.9 Outline of the thesis

Chapter 1 introduces the research area, the motivation of the research and general description on WSNs and objectives of the research.

Chapter 2 describes the previous works of other researchers. The work on WSNs including the cluster-based routing protocol and the classification of WSNs is discussed in this chapter. Comparison between various routing protocol was done.

Chapter 3 compares some networks simulators that are available to implement the proposed algorithm.

Chapter 4 describes the design and implementation. The design of the algorithm is described. And the implementation is explained.

Chapter 5 discusses the simulation and its results, with detailed analysis.

Chapter 6 discusses the achieved result. And make recommendations.

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